Chapter 4
Operation and Maintenance

4-1. General

Problems may occur following many years of trouble-free operation of a dam. This is particularly so for flood control dams which may not be tested by a significant percentage of the maximum head for many years. Also, any period of prolonged severe storming or severe operation such as rapid drawdown warrants additional attention during and immediately after the operation. This is particularly true for control structures such as spillways, conduits, channels, and associated machinery. Another category of higher risk involves those dams of advanced age which may be progressively deteriorating. Rigorous and continuous vigilance, checking, and inspection, for as long as the dam is operational, are necessary for dam safety (James 1990, International Commission on Large Dams 1987, Morrison-Knudsen Engineers 1986, Schurer 1988). Dam operations management policy is covered in ER 1130-2-419.

4-2. Operation and Maintenance Manual

The O&M manual is prepared during the construction phase. The purpose of the O&M manual is to provide guidance and instructions to project personnel for proper operation and maintenance of the facility. A general outline for the O&M manual is given in Appendix I to ER 1130-2-304. The O&M manual contains a narrative summary of the critical features of the dam including design features with safety limits, the more probable failure modes that could lead to structure failure, and a history of problems and how they could adversely affect the structure under stress (ER 1130-2-419).

4-3. Instrumentation and Monitoring

All Corps of Engineers dams are required to have an adequate level of instrumentation to enable the designers to monitor and evaluate the safety of the structure during the construction period and under all operating conditions and furnish data on behavior for application to future designs. Each structure is provided with minimum instrumentation to measure hydrostatic pressure, embankment seepage, and foundation underseepage and displacement of major elements of the structure. Strong motion accelerometers are installed in structures located in seismic regions. In the case of older structures, which were designed using criteria that have been revised due to changes in the state-of-the-art, instrumentation provides most of the data necessary to evaluate the safety of the structure with respect to current standards and criteria. After a project has been operational for several years, scheduled maintenance, repair, and replacement of instrumentation are included in the normal plan of operation (ER 1110-2-110). Detailed information on instrumentation for earth and rockfill dams is given in EM 1110-2-2300 and EM 1110-2-1908. Information on instrumentation for concrete dams is given in EM 1110-2-2200 and EM 1110-2-4300 (see also Lindsey et al. 1986, Keeter et al. 1986, Currier and Fenn 1986, and O'Neil 1989). Full reliance is not placed on instrumentation to forecast unsatisfactory performance, since it is impractical to install enough instrumentation to monitor every possible problem area. An extremely important adjunct to an adequate instrumentation program is visual observation to determine evidence of distress (Duscha 1982). Project personnel receive extensive training in basic engineering considerations pertaining to major structures, with procedures for surveillance, monitoring, and reporting of potential problems, and with emergency operations (discussed in Chapter 7).

4-4. Initial Reservoir Filling

a. General. The "initial reservoir filling" is defined as a deliberate impoundment to meet project purposes and is a continuing process as successively higher pools are attained for flood control projects. The initial reservoir filling is the first test of the dam to perform the function for which it was designed. In order to monitor this performance, the rate of filling should be controlled to the extent feasible, to allow as much time as needed for a predetermined surveillance program including the observation and analysis of instrumentation data (Duscha and Jansen 1988). A DM on initial reservoir filling has been required for all new Corps of Engineers reservoir projects since 1979.

b. Design memorandum. As a minimum, the DM on initial reservoir filling will include:

(1) The preferred filling rate and the available options to control the rate of reservoir rise.

(2) The surveillance necessary to detect most likely occurring problems.

(3) A plan for reading the instruments and evaluating the data.

(4) A plan for inspecting the dam and down stream areas.

(5) Instructions for observers on conditions that require immediate attention of personnel authorized to make emergency decisions.

(6) An emergency plan listing responsibilities, name, and/or positions, telephone numbers and radio frequencies to be used.

c. Existing Corps reservoir projects. Existing operational projects, where the maximum pool (top of flood pool) has not been experienced, will be reviewed for compliance with requirements as outlined in paragraph 4-4.*b*. For those conditions where contingency plans have not been documented and potential danger exists due to filling and/or impounded storage, a report is required outlining those plans. The document may be titled "Flood Emergency Plan" providing that additional initial filling requirements are deemed not to have significant potential impacts on the safety of the structure (EM 1110-2-3600).

4-5. Periodic Inspection and Continuing Evaluation

a. General. A formal program for periodic inspection and continuing evaluation of completed Corps of Engineers projects was established in 1965. Under this program, structures whose failure or partial failure would endanger the lives of the public or cause substantial property damage are periodically evaluated to ensure their structural safety, stability, and operational adequacy. Inspections and evaluations are performed by teams of experienced design, construction, and operations engineers. The evaluations are aided by instrumentation programs (Duscha 1982). Instructions for periodic inspection and continuing evaluation of dams are given in ER 1110-2-100. Additional information on inspection of dams is available (Federal Emergency Management Agency 1979, Colorado Division of Disaster Emergency Services 1987, Reed 1987). The periodic inspection program has one potentially dangerous aspect in that engineers might be tempted to place too much reliance on it and assume that a project once inspected has a guarantee of safety until the next inspection. The thorough occasional inspection is invaluable but cannot take the place of day-to-day observation by operating personnel for detection of potentially dangerous problems at an early and repairable stage (James 1990).

b. Scope of inspections. Corps of Engineers civil works structures such as dams, powerhouses, and appurtenant dam structures (intake and outlet works, spillways, and tunnels) will be periodically inspected in accordance with procedures in Appendix A of ER 1110-2-100 to detect conditions of significant distress or operational inadequacy.

c. Frequency of inspections. The first periodic inspection is carried out immediately after topping out and prior to impoundment of the pool for new earth and rock-fill dams. The initial inspection of concrete dams is accomplished immediately prior to impoundment of reservoir water. The second inspection for new earth and rock-fill dams is made at a reasonable stage of normal operating pool. The second inspection of concrete dams is made when the reservoir water attains the normal operating pool, and in either case no later than one year after initial impoundment has begun. Subsequent inspections for earth and rock-fill dams and concrete dams are made at one-year intervals for the following three years, at two-year intervals for the next four years and then extended to five-year intervals if warranted by the results of the previous inspections (ER 1110-2-100).

d. Procedure. A systematic plan is established for the inspection of features related to the safety and stability of the structure and to the operational adequacy of the project. Operational adequacy means the inspecting, testing, operating, and evaluation of those components of the project whose failure or failure to operate properly would impair the operational capability and/or usability of the structure. These components include, but are not limited to:

(1) Flood and outlet control gates (including flood gates in levees and flood walls).

(2) Navigation lock gates and valves.

(3) Emergency closure gates.

(4) Associated hoists and operating machinery (including safety devices such as limit switches and fail-safe interlocks).

(5) Flood control pumps and related equipment.

(6) Cathodic protection systems.

Details concerning the systematic inspection plan are given in Appendix A of ER 1110-2-100.

e. Reports.

(1) Pre-inspection brochure. A technical brochure is prepared in advance of each project inspection to familiarize inspection team members with general features of the project. This brochure includes a technical summary of the structural, material, and foundation conditions; instrumentation data; and a list of the deficiencies found in previous inspections, if pertinent, and the status of remedial actions recommended. Also, the brochure should include, as appropriate, pertinent project data, layout and typical section drawings, summaries of subsurface soil profiles and boring logs, and the checklist developed for conducting the inspection (ER 1110-2-100, Duscha and Jansen 1988).

(2) Initial and subsequent reports. A condition report will be prepared to present the results of each general project inspection. Report No. 1 (report of initial inspection) will provide a general project description and present the results of the initial inspection. Reports of subsequent inspections will be supplementary to the initial report and will focus on changed conditions noted since the previous inspection. A status report on recommended remedial measures not completed prior to approval of the previous inspection report will also be included (ER 1110-2-100, Duscha and Jansen 1988).

4-6. Reporting Distress

a. Guidance. Evidence of distress at, or potential failure of, dams is to be reported in accordance with the guidance set forth in ER 1110-2-101. Evidence of distress will be immediately reported to the district office. Where engineering evaluation of the evidence of distress indicates the need for immediate remedial action, the district commander will immediately report such conditions through command channels to the HQUSACE Dam Safety Officer who is the Chief of the Engineering Division, Directorate of Civil Works. Each USACE Command will also establish procedures for notification of the major subordinate command and district Dam Safety Officer and coordination of all information with their counterparts in the Emergency Management element. The HQUSACE Dam Safety Officer will notify the Director of Civil Works, and the Commander, USACE. If the HQUSACE Dam Safety Officer cannot be contacted, the reporting field office will follow the notification sequence as outlined in Appendix A of ER 1110-2-101.

b. Examples. Examples of evidence of distress include, but are not limited to:

(1) Significant sloughs, settlement, or slides in embankments such as earth or rockfill dams, urban levees, and bridge abutments or slopes of spillway, channels, locks, and dam abutments.

(2) Evidence of piping, muddy water boils in the area of a structure such as embankments, abutments, dam monoliths, lock walls, or cofferdams.

(3) Abnormal increase or decrease of flow from foundation drains, structural joints, or face drains of concrete dams.

(4) Any increase in seepage quantities through or under embankments or in abutments.

(5) Any increase or decrease in pore water pressure in either embankments or their foundations or abutments.

(6) Any increase or decrease in uplift pressures under concrete structures.

(7) Unusual vertical or horizontal movement or cracking of embankments or abutments.

(8) Significant cracking of mass concrete structures either during construction or after completion.

(9) Sinkholes or localized subsidence in the foundation of or adjacent to embankments or other structures.

(10) Excessive deflection, displacement, or vibration of concrete structures (e.g. tilting or sliding of intake towers, bridge piers, lock wall, floodwalls).

(11) Erratic movement, binding, excessive deflection, or vibration of outlet and spillway gates.

(12) Significant damage to any structure (e.g., barge damage to bridge piers or lock walls or ice flow damage to intake towers and access bridge piers).

(13) Significant damage to, or changes in, structures, foundations, reservoir levels, groundwater conditions, and adjacent terrain as a result of seismic events of local or regional areas. Special inspections of such damages will be made immediately following the event as described in ER 1110-2-1802.

(14) Any other indications of distress or potential failure that could inhibit the operation of a project or endanger life or property.

(15) Excessive vibration, binding, unusual noises, movements, or deflections of gate hoist operatiing equipment.

(16) Actual hydraulic equipment operating pressure in excess of 125 percent of the normal operating pressure. Electric motor operating equipment overheating or stalling.

(17) Erratic movement or unusual sounds, such as bumping, jumping, or popping of lock miter gates.

(18) Wire rope lifting cables or lifting chains having broken strands or deformed, worn, or severely corroded links.

(19) Frequent power interruptions.

(20) Excess movement of penstock flexible couplings.

(21) Penstocks or turbine spiral cases that show signs of distress such as deformation or cracking.

(22) Failure of major mechanical or electrical equipment at local flood protection projects.